

PAINT FILM FORMING METHOD

Technical Field

5 This invention relates to a method of forming paint film
excelling in low temperature-curability, adherability and finishing
property on rigid resin parts for motor vehicles such as door mirrors,
wheel caps, door handles, resin fenders, radiator grilles, aeroparts
and the like.

10 **Background Art**

An important performance required for clear paints applied
onto parts of motor vehicles made of rigid resin (e.g., ABS resin, PC
resin and the like) such as door mirrors, wheel caps, door handles
and aeroparts is that they can form paint film of excellent finish
15 appearance associated with leveling property, gloss and sharpness in
color.

Paint film excelling in finish performance, paint film
performance and paint stability can be provided by clear paint whose
chief ingredients are acrylic resin and curing agent such as
20 polyisocyanate and which is currently used for painting said rigid
resin parts of motor vehicles.

Whereas, due to energy saving in painting line by low-
temperature, short-time baking and productivity improvement by
increased conveyer speed, recently the baking conditions
25 (temperature-time) of rigid resin parts have changed to 60–70°C-
10–25 minutes, preferably 65–70°C-15–20 minutes, from
conventional 80–90°C-40–60 minutes. Hence, development of clear
paint which can form paint film showing good tack property (i.e., free
of tackiness and does not retain fingerprints of persons who touch the
30 film) after being baked under such conditions and left standing at
room temperature and excelling in finish performance, film
performance and paint stability is in demand.

Heretofore, a paint comprising non-water-dispersible
copolymer-containing liquid and acrylic resin is known (cf. JP 2002-
35 326051A) to be suitable for painting ABS resin material. However,

while this paint forms a cured film upon being baked at 75°C for 30 minutes, it is subject to a problem that it develops a certain defect in either one of the film performance, finish performance and paint stability, when baked at a temperature lower than that for a shorter time.

Disclosure of the Invention

An object of the present invention is to provide a paint film forming method which can form on rigid resin parts a film excelling in finish performance, film performance and paint stability, by baking at a low temperature for a short time.

We have now discovered that the above object can be accomplished by using a clear paint which contains an acrylic resin obtained by copolymerization of a monomeric mixture having a specific composition and a curing agent at a specific ratio, and come to complete the present invention.

Thus, the present invention provides a paint film forming method comprising applying color base paint onto rigid resin parts and then clear paint and curing the two paint films, which is characterized by using, as said clear paint, a clear paint comprising 60–90% by weight of a hydroxyl-containing acrylic resin (A) and 10–40% by weight of a curing agent (B), based on the combined solid content of the acrylic resin (A) and the curing agent (B),

said acrylic resin (A) having a hydroxyl value of 80–160 mgKOH/g and being prepared by radical-copolymerizing (a) 8–30% by weight of a primary hydroxyl-containing monomer selected from 4-hydroxybutyl (meth)acrylate monomers and ϵ -caprolactone-modified vinyl monomers obtained by ring-opening polymerization of ϵ -caprolactone with hydroxyalkyl (meth)acrylate; (b) 10–40% by weight of secondary hydroxyl-containing monomer; and (c) 30–82% by weight of still other polymerizable unsaturated monomer.

Said clear paint excels in low temperature-curability and, according to the present invention, can form paint film excelling in finish performance, film performance and paint stability on rigid resin parts, upon baking at a low temperature for a short time.

Hereinafter the method of the present invention is explained in further details.

Objects to be painted

5 The articles to be painted, i.e., the objects to which the method of this invention is to be applied, are parts of motor vehicles such as door mirrors, wheel caps, door handles, aeroparts and the like which are made of rigid resins such as acrylonitrile/butadiene/styrene resin (ABS resin) or polycarbonate resin (PC resin).

10 According to the method of the present invention, these rigid resin-made parts are painted with color base paint and thereafter with clear paint.

Color base paint

15 Color base paint is applied onto said rigid resin-made parts prior to application of clear paint, and as such, per se known color base paint having good adherability to rigid resin can be used. Specifically, for example, one-package color base paint comprising polyester polyol having a hydroxyl value of 40–120 and aliphatic
20 and/or alicyclic blocked polyisocyanate which is formed by blocking hydroxy compound-modified isocyanurate type polyisocyanate with dialkyl malonate and acetoacetic acid ester can be used.

 As the polyester polyol, a hydroxyl-containing polyester resin having a static glass transition temperature of $-80 - 0^{\circ}\text{C}$, preferably
25 $-65 - -20^{\circ}\text{C}$ and a hydroxyl value of 40–120 mgKOH/g, preferably 60–100 mgKOH/g is suitable. Static glass transition temperature as referred to herein is the temperature of the first transition point in the low temperature side baseline, when a sample is taken into a measuring cup, completely removed of the solvent therein by vacuum
30 suction and calorimetric change within a range of $-100^{\circ}\text{C} - +100^{\circ}\text{C}$ is measured at a temperature rise rate of $3^{\circ}\text{C}/\text{min}$. using, for example, a differential scanning calorimeter, DSC-50QTM Model (Shimadzu Seisakujo).

 Such polyester polyol can be prepared, for example, by
35 subjecting polybasic acid and polyhydric alcohol to an esterification

reaction under a condition of hydroxyl excess, following a method known per se. Polybasic acid is a compound having at least two carboxyl groups per molecule, examples of which include phthalic, isophthalic, terephthalic, tetrahydrophthalic, hexahydrophthalic, pyromellitic, itaconic, adipic, sebacic, azelaic, Himic®, succinic and HET acids, and anhydrides thereof. Polyhydric alcohol is a compound having at least two hydroxyl groups per molecule, examples of which include ethylene glycol, diethylene glycol, triethylene glycol, propylene glycol, neopentyl glycol, butylene glycol, hexanediol, trimethylolethane, trimethylolpropane, pentaerythritol, dipentaerythritol and sorbitol. Introduction of hydroxyl groups into a polyester can be conducted by, for example, concurrent use of polyhydric alcohol having at least three hydroxyl groups per molecule. Static glass transition temperature of such polyester polyol can be optionally adjusted by varying kinds and use ratios of these polybasic acids and polyhydric alcohols.

Said aliphatic and/or alicyclic blocked polyisocyanate, which is used as the curing agent, is formed by blocking hydroxy compound-modified isocyanurate type polyisocyanate with dialkyl malonate and acetoacetic acid ester. The modification of isocyanurate-type polyisocyanate with hydroxy compound signifies an urethanation reaction between isocyanate groups and hydroxyl groups, which can be conducted either before or after isocyanuration of the polyisocyanate. In particular, it is preferred to carry it out before the isocyanuration.

As the polyisocyanate compounds to be isocyanurated, aliphatic or alicyclic diisocyanate compounds having two isocyanate groups per molecule are preferred, examples of which include tetramethylene diisocyanate, pentamethylene diisocyanate, hexamethylene diisocyanate, trimethylhexamethylene diisocyanate, lysine diisocyanate, isophorone diisocyanate, bis(isocyanatomethyl)cyclohexane and dicyclohexylmethane diisocyanate. Of these, hexamethylene diisocyanate and isophorone diisocyanate are particularly preferred because they contribute to give paint film of excellent weatherability.

Hydroxy compounds to be used for the modification are the compounds having one, two or more hydroxyl groups per molecule, examples of which include monohydric alcohols such as methanol, ethanol, isopropanol and phenol; dihydric alcohols such as ethylene glycol, propylene glycol, butanediol, pentanediol, hexanediol, cyclohexanediol, dimethylolcyclohexane, neopentyl glycol and trimethylpentanediol; polyhydric alcohols such as trimethylolpropane, glycerine and pentaerythritol; and hydroxyl-containing resins such as hydroxyl-containing acrylic resins, hydroxyl-containing polyester resins and hydroxyl-containing polyether resins.

Suitable use rate of said hydroxy compound is such that makes the ratio of hydroxyl groups to isocyanate groups fall within a range of 0.1–20 equivalent%, preferably 0.5–15 equivalent%, inter alia, 1–10 equivalent%.

The urethanation reaction can be conducted by a method known per se, in the presence of a catalyst. Examples of useful catalyst include hydroxides or organic acid salts of tetraalkylammonium such as tetramethylammonium, tetraethylammonium and tetrabutylammonium; hydroxides or organic acid salts of hydroxyalkylammonium such as trimethylhydroxyethylammonium, trimethylhydroxypropylammonium, triethylhydroxyethylammonium and triethylhydroxypropylammonium; alkali metal salts of alkylcarboxylic acids such as acetic acid, caproic acid, octylic acid and myristic acid; salts of said alkylcarboxylic acids with such metals as tin, zinc and lead; and aminosilyl-containing compounds such as hexamethylenedisilazane. These catalysts can normally be used at a concentration level in the isocyanate compound used, within a range of 10 ppm–1% by weight.

The urethanation reaction can be conducted in the presence or absence of organic solvent. As the organic solvent, optional solvent which is inert to isocyanate group can be used. The reaction temperature normally is within a range of 20–160°C, preferably 40–130°C. When the reaction reaches the termination point, preferably it is stopped by deactivating the catalyst with, for example,

sulfonic acid, phosphoric acid and the like. After the reaction, the unreacted materials and organic solvent are eliminated to provide the intended hydroxyl compound-modified isocyanurate type polyisocyanate.

5 Thus obtained isocyanurate type polyisocyanate which is modified with hydroxy compound is then blocked by concurrent use of dialkyl malonate and acetoacetic acid ester.

As dialkyl malonate, for example, dimethyl malonate, diethyl malonate, diisopropyl malonate, di-n-butyl malonate, diethyl
10 methylmalonate, benzylmethyl malonate and diphenyl malonate can be named, and as acetoacetic acid ester, for example, methyl acetoacetate, ethyl acetoacetate, isopropyl acetoacetate, n-propyl acetoacetate, benzyl acetoacetate and phenyl acetoacetate can be named. It is generally suitable to use 30–90 equivalent%, in
15 particular, 50–80 equivalent%, of dialkyl malonate; and 10–70 equivalent%, in particular, 20–50 equivalent%, of acetoacetic acid ester; both to the isocyanate groups. It is permissible to use, besides these two blocking agents, other blocking agent(s) derived from, for example, alcohol, phenol, oxime, amine, acid amide, imidazole,
20 pyridine, mercaptane or the like, within a range not higher than 20 equivalent% to the isocyanate groups. Blocking reaction of the isocyanate groups can be conducted by a method known per se.

Color base paint which can be conveniently used in the present invention is such one-package type color base paint
25 comprising the polyester polyol and blocked polyisocyanate which are obtained in the above-described manner. Generally suitable ratio between the two components is: per 100 parts by weight of the polyester polyol, 10–50 parts by weight, in particular, 25–40 parts by weight, of the blocked polyisocyanate.

30 Such color base paint can be formulated by incorporating coloring pigment into above-described polyester polyol and blocked polyisocyanate, and dissolving or dispersing the blend in organic solvent and/or water. Where necessary, additives for paints such as extender, catalyst or the like may further be added.

35 As the coloring pigments, for example, solid color pigments

such as titanium dioxide, carbon black, chrome yellow, yellow ochre, yellow iron oxide, Hansa yellow, pigment yellow, chrome orange, chrome vermilion, permanent orange, amber, permanent red, brilliant carmine, fast violet, methyl violet lake, ultramarine blue, iron blue, cobalt blue, phthalocyanine blue, pigment green and naphthol green; metallic pigments such as aluminum powder, vapor deposited aluminum, aluminum oxide bronze powder, copper powder, tin powder and micaceous iron oxide; and iridescent pigments such as titanium oxide- or iron oxide-coated mica flakes and mica flakes can be named, but of course useful pigments are not limited to these named above. They can be used each alone or in combination of two or more, to provide solid color paint, metallic paint and iridescent paint.

Color base paint can be applied onto rigid resin-made parts, by adjusting its viscosity to 12–15 seconds/Ford cup #4/20°C, and applying it by such method as air spraying, airless spraying, electrostatic spraying or dipping. Thickness of the paint film is variable according to the kind of rigid resin-made parts to be painted, while generally adequate range is 10–40 μm , in particular, 15–25 μm , based on the cured paint film.

Coated film of the color base paint can be cured where necessary, normally by heating at temperatures of 60–100°C, preferably 70–90°C, for about 5–40 minutes, preferably about 15–30 minutes.

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Clear paint

Clear paint to be applied onto the coated surfaces with color base paint according to the method of this invention comprises hydroxyl-containing acrylic resin (A) and curing agent (B) as essential ingredients, and further, preferably, an oligomer (C). Hereinafter these ingredients are explained in further details.

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Hydroxyl-containing acrylic resin (A):

Hydroxyl-containing acrylic resin (A) is an acrylic resin having a hydroxyl value of 80–160 mgKOH/g, which is obtained by radical

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copolymerization of

- (a) 8–30 wt% of a primary hydroxyl-containing monomer selected from 4-hydroxybutyl (meth)acrylate monomer and ϵ -caprolactone-modified vinyl monomer obtained by ring-opening polymerization of hydroxyalkyl (meth)acrylate with ϵ -caprolactone,
- (b) 10–40 wt% of a secondary hydroxyl-containing monomer, and
- (c) 30–82 wt% of other polymerizable unsaturated monomer.

Said ϵ -caprolactone-modified vinyl monomer useful as above monomer (a) component is obtained by ring-opening polymerization of hydroxyalkyl (meth)acrylate with ϵ -caprolactone, which includes those represented by the following formula (I):



wherein

R^1 is hydrogen or methyl,

R^2 is $\text{C}_2\text{--C}_6$, in particular, $\text{C}_2\text{--C}_3$ alkylene, and

n is an integer of 1–10, preferably 1–5.

In particular, these monomers of above (I) in which R^1 is hydrogen and R^2 is ethylene are preferred. Such ϵ -caprolactone-modified vinyl monomers are known *per se*, and as their commercialized products, for example, PLACCELTM FA-1, PLACCELTM FA-2, PLACCELTM FA-3, PLACCELTM FA-4, PLACCELTM FA-5, PLACCELTM FM-1, PLACCELTM FM-2, PLACCELTM FM-3, PLACCELTM FM-4 and PLACCELTM FM-5 (Daicel Chemical Industries, Ltd.) can be named.

As primary hydroxyl-containing monomer (a), either 4-hydroxybutyl (meth)acrylate monomer or ϵ -caprolactone-modified vinyl monomer can be used alone, or they may be used in combination.

Such monomer (a) component improves reactivity of resultant hydroxyl-containing acrylic resin (A) with curing agent (B) and contributes to low temperature curability of the paint film.

As examples of secondary hydroxyl-containing monomer (b), hydroxyalkyl (meth)acrylate whose alkyl moiety has 3–6, in particular, 3 or 4, carbon atoms, such as 2-hydroxypropyl

(meth)acrylate, 2-hydroxybutyl (meth)acrylate and 3-hydroxybutyl (meth)acrylate; and adducts of (meth)acrylic acid with epoxy-containing compound (e.g., Cardula™ E10, Yuka Shell Epoxy Co.) can be named, 2-hydroxypropyl (meth)acrylate being particularly preferred.

Secondary hydroxyl groups in these monomer (b) component contribute to improve adherability of resulting paint to the color base paint coating.

Other polymerizable unsaturated monomer (c) is any of those copolymerizable with said monomer (a) and/or monomer (b), specific examples including vinyl aromatic compounds such as styrene, α -methylstyrene, vinyltoluene and p-chlorostyrene; C_1 - C_{24} , in particular, C_1 - C_{18} , alkyl esters or cycloalkyl esters of (meth)acrylic acid such as methyl (meth)acrylate, ethyl (meth)acrylate, n-propyl (meth)acrylate, isopropyl (meth)acrylate, n-butyl (meth)acrylate, isobutyl (meth)acrylate, sec-butyl (meth)acrylate, tert-butyl (meth)acrylate, hexyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, n-octyl (meth)acrylate, decyl (meth)acrylate, lauryl (meth)acrylate, stearyl (meth)acrylate and cyclohexyl (meth)acrylate; C_2 - C_{18} alkoxyalkyl esters of (meth)acrylic acid such as methoxybutyl (meth)acrylate, methoxyethyl (meth)acrylate and ethoxybutyl (meth)acrylate; amino-containing acrylic monomers such as N,N-dimethylaminoethyl (meth)acrylate, N,N-diethylaminoethyl (meth)acrylate, N,N-dimethylaminopropyl (meth)acrylate, N,N-di-tert-butylaminoethyl (meth)acrylate and N,N-dimethylaminopropyl (meth)acrylic amide; carboxyl-containing acrylic monomers such as (meth)acrylic acid, crotonic acid, itaconic acid, maleic acid and fumaric acid; and poly-unsaturated acrylic monomers such as ethylene glycol di(meth)acrylate, diethylene glycol di(meth)acrylate, triethylene glycol di(meth)acrylate, tetraethylene glycol di(meth)acrylate, 1,3-butylene glycol di(meth)acrylate, 1,4-butanediol diacrylate, glycerine di(meth)acrylate, glycerin tri(meth)acrylate, trimethylolpropane di(meth)acrylate, trimethylolpropane tri(meth)acrylate, pentaerythritol di(meth)acrylate, pentaerythritol tri(meth)acrylate, pentaerythritol tetra(meth)acrylate,

dipentaerythritol penta(meth)acrylate, hydroxyisocyanurate tri-(meth)acrylate, neopentylglycol diacrylate, 1,6-hexanediol diacrylate, glycerolallyloxy di(meth)acrylate, 1,1,1-tris(hydroxymethyl)ethane di(meth)acrylate, 1,1,1-tris(hydroxymethyl)ethane tri(meth)acrylate, 5 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 3-hydroxypropyl (meth)acrylate and 4-hydroxybutyl (meth)acrylate. Of these, particularly styrene, alkyl esters of (meth)acrylic acid and (meth)acrylic acid are preferred. They can be used each alone or in combination, according to the characteristic properties desired for 10 individual hydroxyl-containing acrylic resin (A).

Said hydroxyl-containing acrylic resin (A) can be prepared by radical copolymerizing above-described primary hydroxyl-containing monomer (a), secondary hydroxyl-containing monomer (b) and other polymerizable unsaturated monomer (c), following a radical 15 polymerization method known per se, for example, in the presence of a polymerization initiator, in an atmosphere of an inert gas such as gaseous nitrogen, at about 50°C–about 300°C, preferably at about 60°C–about 250°C, in an organic solvent, for about 1–about 24 hours, preferably for about 2–about 10 hours.

20 The use rates of the monomers in that occasion can be as follows, based on the combined amount of the monomers (a), (b) and (c):

monomer (a): 8–30 wt%, preferably 10–25 wt%, inter alia,
15–20 wt%

25 monomer (b): 10–40 wt%, preferably 15–35 wt%, inter alia,
20–30 wt%

monomer (c): 30–82 wt%, preferably 40–75 wt%, inter alia,
50–65 wt%.

30 Where monomer (a) is less than 8 wt%, the resulting clear paint exhibits insufficient low temperature curability. Whereas, when it exceeds 30 wt%, paint stability of the clear paint might be impaired. Also when monomer (b) is less than 10 wt%, the clear paint has insufficient adherability, and when it exceeds 40 wt%, 35 stability of the clear paint might be impaired.

As examples of the polymerization initiator, benzoyl peroxide, di-tert-butylhydroperoxide, azobisdimethylvaleronitrile and azobisisobutyronitrile can be named. As examples of the organic solvent to be used for the radical polymerization reaction, aromatic hydrocarbon solvents such as toluene and xylene; ketone solvents such as methyl isobutyl ketone and cyclohexanone; and alcohol solvents such as n-butanol, ethyl cellosolve, butyl cellosolve, methoxypropanol and diethylene glycol monobutyl ether can be named. These organic solvents can be used each alone or more than one of them can be used in combination.

Thus obtained hydroxyl-containing acrylic resin (A) can have a hydroxyl value within a range of 80–160 mgKOH/g, preferably 90–150 mgKOH/g, inter alia, 100–140 mgKOH/g. Said hydroxyl-containing acrylic resin (A) generally desirably has an weight-average molecular weight within a range of 5,000–20,000, preferably 7,500–17,500, inter alia, 10,000–15,000; and an acid value within a range of 0–40 mgKOH/g, preferably 0.5–30 mgKOH/g, inter alia, 1–20 mgKOH/g.

20 Curing agent (B):

Curing agent (B) which is used for the clear paint according to the invention is a compound capable of reacting with the hydroxyl groups in said hydroxyl-containing acrylic resin (A) to cure the same acrylic resin (A), and preferably polyisocyanate compound can be used.

As examples of the polyisocyanate compound, aliphatic diisocyanates such as hexamethylene diisocyanate and trimethylhexamethylene diisocyanate; alicyclic diisocyanates such as hydrogenated xylylene diisocyanate and isophorone diisocyanate; aromatic diisocyanates such as tolylene diisocyanate and 4,4'-diphenylmethane diisocyanate; polyisocyanate compounds having at least 3 isocyanate groups such as triphenylmethane-4,4',4''-triisocyanate, 1,3,5-triisocyanatobenzene, 2,4,6-triisocyanatotoluene and 4,4'-dimethyldiphenylmethane-2,2',5,5'-tetraisocyanate; adducts of these organopolyisocyanates with polyhydric alcohols, low

molecular weight polyester resins or water; cyclized polymers of organopolyisocyanates as above-named or isocyanate-biuret can be named.

As these polyisocyanate compounds, commercialized products
5 such as Burnock™ D-750, Burnock™ D-800, Burnock™ DN-950, Burnock™ DN-970 and Burnock™ DN-15-455 (Dainippon Ink & Chemicals, Inc.); Desmodur™ L, Desmodur™ N, Desmodur™ HL, Desmodur™ 3200, Desmodur™ 3300 and Desmodur™ 3500 (Sumika Bayer Urethane Co.); Takenate™ D-102, Takenate™-202,
10 Takenate™-110, Takenate™-123N, Takenate™-140N, Takenate™-160N, Takenate™-165N and Takenate™-170N (Mitsui Takeda Chemicals, Inc.); Coronet™ EH, Coronet™ L, Coronet™ HL and Coronet™ 203 (Nippon Polyurethane Industry Co., Ltd.); and Duranate™ 24A-90CX (Asahi Kasei Chemicals Corporation) can be
15 used.

In these polyisocyanate compounds, isocyanate groups may be blocked. As blocking agent for that purpose, for example, oxime, phenol, alcohol, lactam, malonic acid ester, mercaptane and the like can be named. As blocked polyisocyanate compounds, those
20 available in the market can be used, typical products being, for example, Burnock™ D-550 (Dainippon Ink & Chemicals, Inc.), Takenate™ B-815-N (Mitsui Takeda Chemicals, Inc.), Additol™ VXL-80 (Hoechst AG, Germany), Coronet™ 2507 (Nippon Polyurethane Industry Co., Ltd.) and Desmodur™ N3500 (Sumika Bayer Urethane
25 Co., Ltd.).

Clear Paint:

The clear paint to be applied onto the paint film of earlier described color base paint according to the present invention
30 comprises the above-described hydroxyl-containing acrylic resin (A) and curing agent (B), the blend ratio of the acrylic resin (A) and the curing agent (B) being, based on the total solid content of said two ingredients, 60–90 wt%, preferably 65–85 wt%, inter alia, 70–80 wt%, of the acrylic resin (A) and 10–40 wt%, preferably 15–35 wt%, inter
35 alia, 20–30 wt%, of the curing agent.

Into the clear paint, furthermore, hydroxyl-containing oligomer (C) may be incorporated, to improve leveling property and adherability of the paint film, where necessary.

Said hydroxyl-containing oligomer (C) includes reaction products of carboxyl-containing compound with epoxy-containing compound, which have at least the hydroxyl group(s) formed by ring-opening esterification reaction between the carboxyl group(s) of the carboxyl-containing compound and the epoxy group(s) of the epoxy-containing compound used in the reaction.

“Carboxyl-containing compound” is a compound having one, two or more carboxyl groups per molecule, of which examples include monocarboxylic acids such as acetic acid, propionic acid, butyric acid, 2-ethylhexanoic acid, octanoic acid, dodecanoic acid, palmitic acid, stearic acid, oleic acid, pivalic acid, versatic acid and benzoic acid; polycarboxylic acids such as succinic acid, adipic acid, azelaic acid, sebacic acid, dodecanedioic acid, tetrahydrophthalic acid, phthalic acid, butanetricarboxylic acid, butanetetracarboxylic acid and anhydrous trimellitic acid; and hydroxy acids such as glycolic acid, lactic acid, malic acid, citric acid, tartaric acid, hydroxypivalic acid, dimethylolpropionic acid, dimethylol butanoic acid and gluconic acid. Anhydrides of these acids also are useful, or reaction products of the anhydrides with glycols can be utilized. Specific examples include reaction product of trimethylolpropane with hexahydrophthalic anhydride or that of trimethylolpropane with succinic anhydride. Of these, hydroxy acids or reaction products of the anhydrides with glycols, in which hydroxyl groups and carboxyl groups are concurrently present, are preferred. Their use enables introduction of many hydroxyl groups into said oligomer (C). In particular, hydroxy acids are advantageous.

An “epoxy-containing compound” contains one, two or more epoxy groups per molecule, and such compounds known per se can be used. For example, (a) glycidol, (b) epoxy-containing compounds obtained by etherification reaction of hydroxyl-containing compounds with epihalohydrin, (c) epoxy-containing compounds obtained by esterification reaction of carboxyl-containing compounds with

epihalohydrin, and (d) epoxy-containing compounds obtained by reaction of unsaturated groups with peroxide, can be named. Glycidol (a) is 2,3-epoxy-1-propanol, which can be obtained, for example, by reaction of allyl alcohol with benzoic or tungstic acid, and hydrogen peroxide.

Examples of the hydroxyl-containing compounds used for preparation of said epoxy-containing compounds (b) include: aromatic hydroxyl-containing compounds such as phenol, bis-phenol A, bis-phenol F, phenol-novolak resin, orthocresol-novolak resin and bromides of the foregoing; alicyclic hydroxyl-containing compounds such as hydrogenated bis-phenol A; C₁-C₂₀ aliphatic monohydric alcohols such as methanol and ethanol; and C₂-C₂₀ aliphatic polyols such as ethylene glycol, propylene glycol, hexanediol, diethylene glycol, neopentyl glycol, glycerine, trimethylolpropane, pentaerythritol and dipentaerythritol. As epihalohydrins, epichlorohydrin can be favorably used. The etherification reaction of those hydroxyl-containing compounds with epihalohydrin can be conducted by a method known per se. As commercially available products corresponding to the epoxy-containing compound (b), for example, Denacol™ EX-313, Denacol™ EX-321, Denacol™ EX-421 and Denacol™ EX-611 (Nagase Industries) can be named.

As carboxyl-containing compounds useful for preparing the epoxy-containing compound (c), for example, those carboxyl-containing compounds exemplified in connection with preparation of the acrylic resin (A) can be favorably used. The esterification reaction of such carboxyl-containing compounds with epihalohydrin such as epichlorohydrin can be conducted by a method known per se. As commercially available products corresponding to the epoxy-containing compound (c), for example, Cardula™ E10 (Yuka Shell Epoxy Co.), Glydexx™ N10 (Exxon) and Araldite™ PT910 (Ciba Geigy Co.) can be named.

As commercially available products corresponding to the epoxy-containing compound (d), for example, Celloxide™ 2021 and Celloxide™ 3000 (Daicel Chemical Industries, Ltd.) can be named.

Of these epoxy-containing compounds, glycidyl esters having

hydrophobic groups can be used with particular advantage.

While the ring-opening esterification reaction of above-described carboxyl-containing compounds with epoxy-containing compounds can be conducted at room temperature, it is normally
5 preferred to carry it out under heating to, for example, 100–160°C, in particular, 115–150°C, in the absence of catalyst.

Thus obtained oligomer (C) has at least two hydroxyl groups per molecule, and generally has a hydroxyl value within a range of 200–800 mgKOH/g, preferably 250–700 mgKOH/g, inter alia,
10 300–600 mgKOH/g, and a weight-average molecular weight within a range not higher than 1,000, preferably 200–850, inter alia, 300–700.

Such a hydroxyl-containing oligomer (C) can be used generally within a range of 1–20 wt%, preferably 3–18 wt%, inter alia, 5–15 wt%, based on the total solid content of the acrylic resin (A) and the
15 curing agent (B).

With the clear paint, still other ingredients may be incorporated where necessary, such as modifying resin, e.g., ordinary acrylic resin, polyester resin, urethane resin and alkyd resin; additives to paint such as ultraviolet absorber, photostabilizer,
20 surface regulating agent and antisetting agent; pigment of an amount not substantially impairing transparency of the paint film, e.g., coloring pigment, metallic pigment and iridescent pigment; and catalyst such as organometallic compound, e.g., tin octylate, dibutyltin di(2-ethylhexanoate), dioctyltin di(2-ethylhexanoate),
25 dioctyltin diacetate, dibutyltin dilaurate, dibutyltin oxide, monobutyltin trioctate, lead 2-ethylhexanoate, zinc octylate and calcium octylate, acid, e.g., p-toluenesulfonic acid, dodecylbenzenesulfonic acid, dinonylnaphthalenesulfonic acid, butylphosphoric acid and octylphosphoric acid, and their amine
30 neutralized products.

Where free polyisocyanate compound is used as the curing agent (B) in the clear paint, there is a possibility that the hydroxyl groups of the acrylic resin (A) and the isocyanate groups in the polyisocyanate compound react to form a gel, and preferably these
35 two components should be separately kept as two-component type

package, particularly when their storage time is going to be prolonged over many hours, so that they are mixed immediately before use of the paint.

The clear paint is applicable onto cured or uncured base color paint-applied surface, after being adjusted of its viscosity to 14–20 seconds/Ford cup #4/20°C, by such means as air spraying, airless spraying, electrostatic finishing or dipping. The thickness of the applied paint film is not subject to strict limitation, but is variable depending on the kind of the object rigid resin-made parts or else, but generally adequate range is 15–80 μm , in particular, 20–40 μm .

The clear paint can be applied onto rigid resin-made parts which have been coated with color base paint as earlier described, the coating being optionally given a setting treatment at room temperature and left uncured or being cured as earlier described, and then baked. Thus a multi-layered paint film can be formed by 2 coat 1 bake system or 2 coat 2 bake system.

The coating film of the clear paint can be substantially completely cured by baking at such low temperatures and short time as 60–70°C/10–25 minutes, preferably 65–70°C/15–20 minutes.

Thus, according to the method of the present invention, a multi-layered paint film can be formed on rigid resin-made parts without causing any thermal deformation or deterioration of the painted objects. Furthermore, the baked and cured paint film leaves no trace thereon even when a person holds it immediately after its curing. The film also is resistant to scars or dents which are apt to be incurred during packing and excels in paint workability.

In the above described method of the present invention, the paint film formed of the clear paint comprising the specific hydroxyl-containing acrylic resin (A) excels in paint stability, low temperature curability and adherability, and its cured film can be readily formed under such low temperature and short time baking conditions as, for example, 60–70°C/10–25 minutes, preferably 65–70°C/15–20 minutes. Furthermore, the clear paint following the present invention is free of tackiness (a property of giving tackiness-free painted surface which does not retain fingerprints of a person who touches it). When

allowed to stand at room temperature for only 30 minutes, the painted surface exhibits such effects that it does not retain traces of gloves or packing materials used during handling of the painted parts and excels also in polishability when refuse or dust lay on the surface.

According to the method of the present invention, therefore, reduction in energy consumption by painting line or productivity improvement by increased conveyer running speed can be accomplished.

Examples

Hereinafter the invention is more specifically explained, referring to working examples, it being understood that the invention is in no way thereby limited. In the following examples, parts and percentages are by weight.

Production Example 1:

Production of acrylic resin No.1

A reactor equipped with a stirrer, cooler, temperature-regulator, nitrogen inlet pipe and a dropping funnel was charged with 45 parts of an organic solvent, and the inside atmosphere was replaced with nitrogen. The content was heated under stirring until the inside temperature reached 130°C. Then a monomeric mixture of the following composition was added dropwise, consuming 3 hours.

	<u>Parts</u>
4-Hydroxybutyl acrylate	5
ϵ -Caprolactone-modified vinyl monomer	15
2-Hydroxypropyl acrylate	5
2-Hydroxypropyl methacrylate	15
Styrene	25
Methyl methacrylate	10
Isobutyl methacrylate	18
n-Butyl acrylate	5
Acrylic acid	2

Di-tert-butylhydroperoxide

8

After termination of the dropwise addition, the system was allowed to age for 30 minutes at 130°C, to provide an acrylic resin
5 No.1 having an acid value of 16 mgKOH/g, a hydroxyl value of 122 mgKOH/g, a weight-average molecular weight of 12,000 and a solid content of 60%.

Production Examples 2-7:

10 Production of acrylic resin Nos.2-7

Repeating the procedures of Production Example 1 except that the monomeric mixtures of the composition as shown in Table 1 were used, acrylic resins No.2-No.7 were obtained.

Table 1

	Production Example 1	Production Example 2	Production Example 3	Production Example 4	Production Example 5	Production Example 6	Production Example 7
Acrylic resin	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Styrene	25	25	35	25	25	30	25
Methyl methacrylate	10			10	10	10	10
n-Butyl acrylate	5	10	11	5	5	5	5
Isobutyl methacrylate	18	18	18	30	18	25	13
4-Hydroxybutyl acrylate	5		14	5	5		20
FM-3 (note 1)	15	20			15	14	
2-Hydroxyethyl acrylate					15		
2-Hydroxyethyl methacrylate				3			
2-Hydroxypropyl acrylate	15	10	5	15		14	5
2-Hydroxypropyl methacrylate	5	15	15	5	5		20
Acrylic acid	2	2	2	2	2	2	2
Di-tert-butylhydroperoxide	8	8	8	8	8	8	8
Solid content (%)	60	60	60	60	60	60	60
Acid value (mgKOH/g)	16	16	16	16	16	16	16
Hydroxyl value (mgKOH/g)	122	125	135	118	129	77	177
Weight-average molecular weight (Mw)	12,000	12,000	12,000	12,000	12,000	12,000	12,000

(note 1) FM-3™: Daicel Chemical Industries, Ltd., ε-caprolactone-modified vinyl monomer of 2-hydroxyethyl acrylate

Production Example 8:

Production of oligomer No.1

A reactor equipped with a stirrer, cooler, temperature-regulator, nitrogen inlet pipe and a dropping funnel was charged with 296 parts of dimethylolbutanoic acid, the inside atmosphere was replaced with nitrogen, and the content was heated to 120°C. Then 490 parts of Cardula™ E10 was added dropwise, consuming 2 hours. Maintaining the temperature of 120°C, the reaction was terminated at the point when the acid value dropped to no higher than 9. Thus obtained oligomer No.1 had a solid content of 98%, a Gardner viscosity (20°C) of Z₆ Z₇, hydroxyl value or 428 mgKOH/g, a number-average molecular weight of 600 and a weight-average molecular weight of 610.

Example 1:

Production of clear paint No.1

Sixty (60) parts (solid content) of acrylic resin No.1, 40 parts (solid content) of Desmodur™ N3300 ^{note 2)} and 10 parts of oligomer No.1 were mixed and the mixture's viscosity was adjusted to 50 seconds (Ford cup # 4/20°C) to provide clear paint No.1.

Examples 2 and 3:

Production of clear paint Nos.2-3

Clear paint Nos. 2 and 3 were obtained in the manner similar to Example 1, except that the respective composition was varied to those shown in Table 2.

Comparative Example 1-4:

Production of clear paint Nos.4-7

Clear paint Nos. 4-7 were obtained in the manner similar to Example 1, except that the respective composition was varied to those as shown in Table 2.

Table 2

	Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
Clear paint	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Acrylic resin (A)	60% Acrylic resin No. 1						
	60% Acrylic resin No. 2	60					
	60% Acrylic resin No. 3		60				
	60% Acrylic resin No. 4			60			
	60% Acrylic resin No. 5				60		
	60% Acrylic resin No. 6					60	
	60% Acrylic resin No. 7						60
Curing agent (B)	Desmodur™ N3300 (note 2)	40	40	40	40	40	40
Oligomer (C)	Oligomer No. 1	10	10	10	10	10	10

(note 2) Desmodur™ N3300: Sumika Bayer Urethane Co., Ltd., isocyanurate type hexamethylene diisocyanate

Preparation of test panels

Onto a degreased ABS resin flat plate ($70 \times 150 \times 3$ mm), Soflex™ #400 (Kansai Paint, metallic primer) was applied to a thickness of $15 \mu\text{m}$, and set for 7 minutes at room temperature.

- 5 Then clear paint Nos. 1–7 each was applied and baked and cured under the conditions of 70°C – 20 minutes, to provide test panels No.1–No.7.

The test was conducted under the following conditions. The results were as shown in Table 3.

Table 3

TEST RESULT

	Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
Test panel	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Pot life of clear paint (note 3)	O	O	O	O	X	O	X
Gel fraction ratio (note 4)	94	94	94	68	95	76	92
Pencil hardness of paint film (note 5)	H	H	H	2B	H	B	H
Tackiness of paint film (note 6)	O	O	O	X	O	Δ	O
Adherability (note 7)	O	O	O	Δ	X	X	O
Finished appearance (note 8)	O	O	O	O	O	O	Δ

(note 3) Pot life of clear paint:

Each of the clear paints was stored for 5 hours at 20°C, and then applied onto a cold-finished mild steel plate to a film thickness of 40–50 µm and cured by baking at 70°C for 20 minutes. Condition of the cured film (transparency, presence of humps and finished appearance) was visually observed and evaluated by the following standard:

○: no abnormality

✕: abnormality observed in paint film

(note 4) Gel fraction ratio:

Each of clear paint No.1–No.7 was applied onto the test panel to a film thickness of 40 µm and baked at 70°C for 20 minutes. The paint film was then peeled off by amalgam method, cut to a fixed size (5 × 5 cm) and weighed (W_1). The film was then immersed in an organic solvent (acetone) for 24 hours (20°C), air-dried and the weight (W_2) of the film after the solvent extraction was measured. Gel fraction ratio (%) was calculated following the equation:

$$\text{gel fraction ratio (\%)} = (W_2 / W_1) \times 100$$

(note 5) Pencil hardness of paint film:

Pencil hardness of the paint film on each test panel applied with the base color paint and each of the clear paints was measured following the method as prescribed by JIS K 5400 8.4.2.

(note 6) Tackiness of paint film:

Extent of surface tackiness was evaluated by touching with the finger:

○: not tacky

△: slightly tacky but no fingerprint left on the surface

✕: tacky and fingerprint was left on the surface.

(note 7) Adherability:

Following the method as prescribed by JIS K 5400 8.5.2, 1 mm

× 1 mm chekerboard pattern tape adhesion test was conducted:

○: not peeling off

△: local peeling

×: whole surface peeling

5

(note 8) Finished appearance:

Finished appearance was visually evaluated based on the following standard:

○: good

10

△: round feeling and gloss unevenness

×: heavy round feeling and surface roughening.